SCT FSI system
Shining light on the ATLAS SCT structure at the LHC

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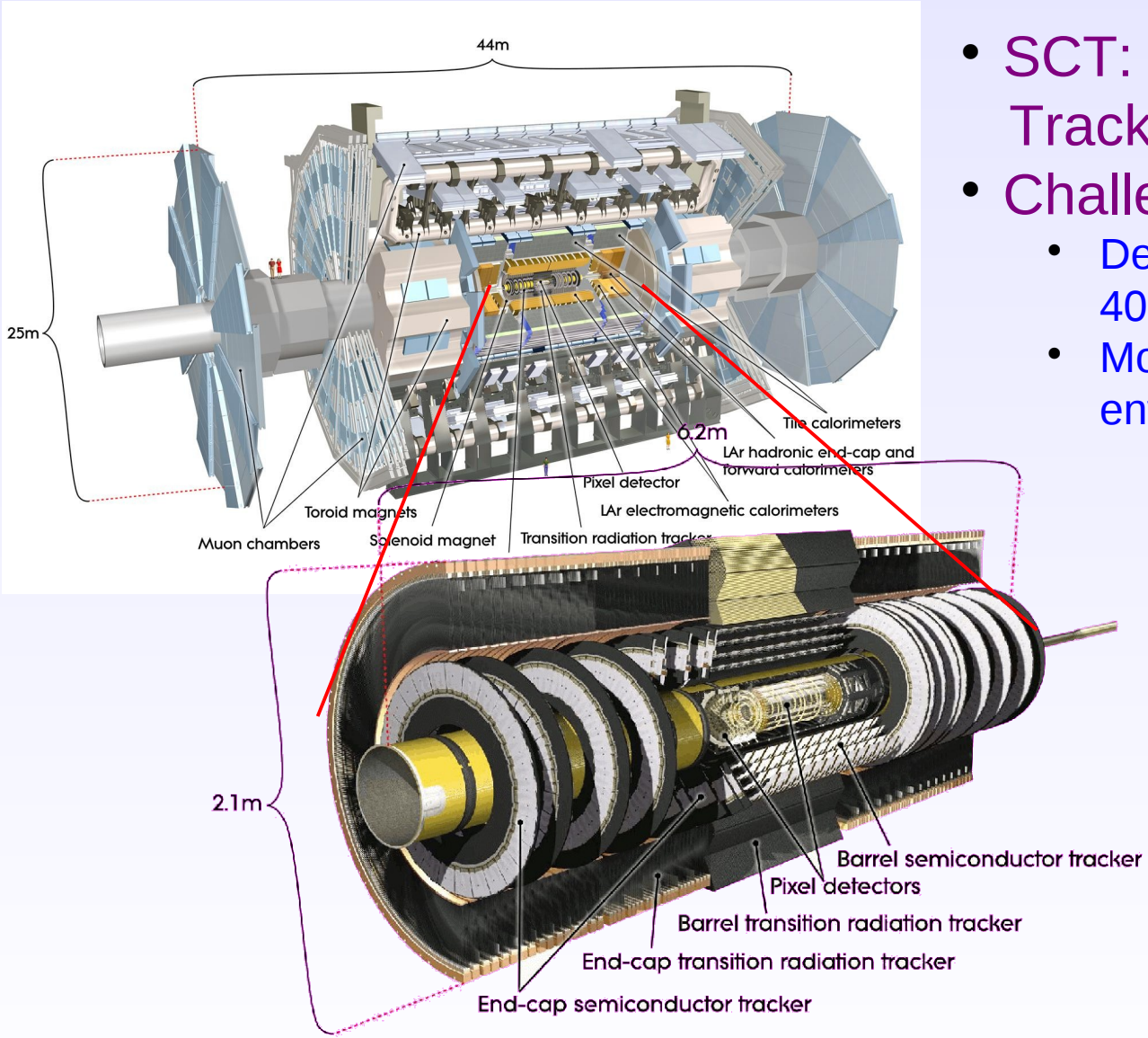
***on behalf of the ATLAS SCT collaboration**

Outline

- Introduction
  - ATLAS and SCT detectors @ LHC
- Frequency Scanning Interferometry for SCT
- FSI data analysis
- FSI performance and results
- Conclusions

ATLAS Inner Detector Alignment



- SCT: SemiConductor Tracker for ATLAS
- Challenge:
  - Determining the position of 4088 Si module
  - Movement induced by environmental conditions

- SCT alignment
  - Primarily using measured charged particle tracks
  - µm-level precision required
  - Stability monitoring => FSI !

Frequency Scanning Interferometry

- What is FSI?
  - Technique developed for ATLAS
  - Measures lengths between known points on a structure
  - Provides monitoring of changes in lengths
- Why FSI?
  - Independent measurement of the SCT structure stability
  - Continuous running (also when ATLAS data not recorded)
  - Cross-check for track-based alignment
- Where is FSI?
  - Monitoring of the entire SCT support structure
- How?
  - Next slide...

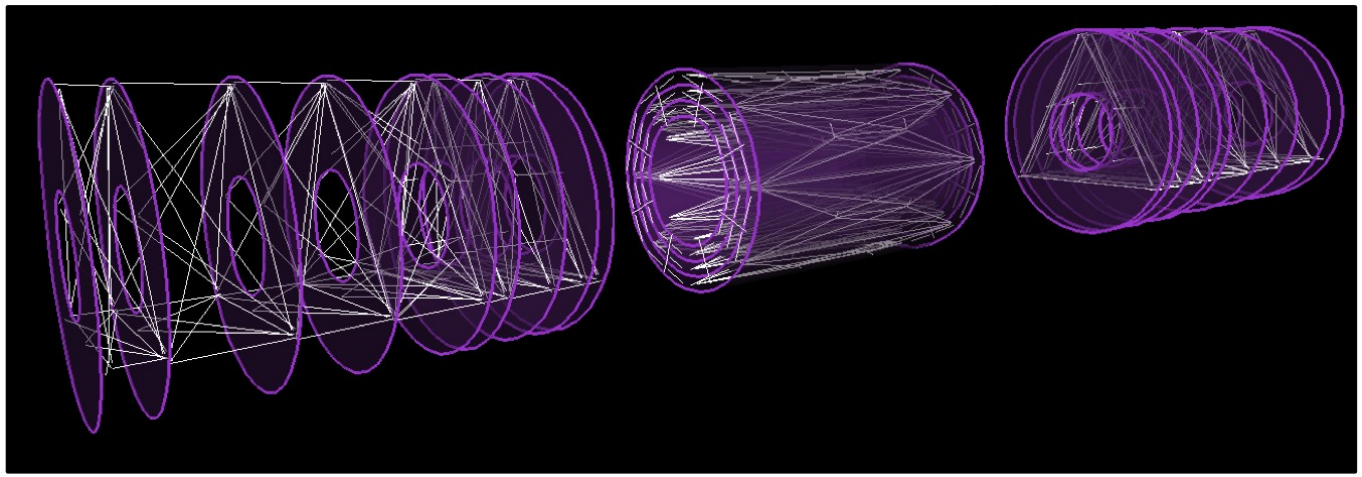
SCT alignment monitoring

Interferometry on a large scale!

- SCT covered by a geodetic grid designed to measure weak mode changes
- 842 individual interferometers, Grid Line Interferometers, attached to the SCT support structure, measured simultaneously

Rendering of the SCT full grid

Barrel (center) and 2 End-Caps



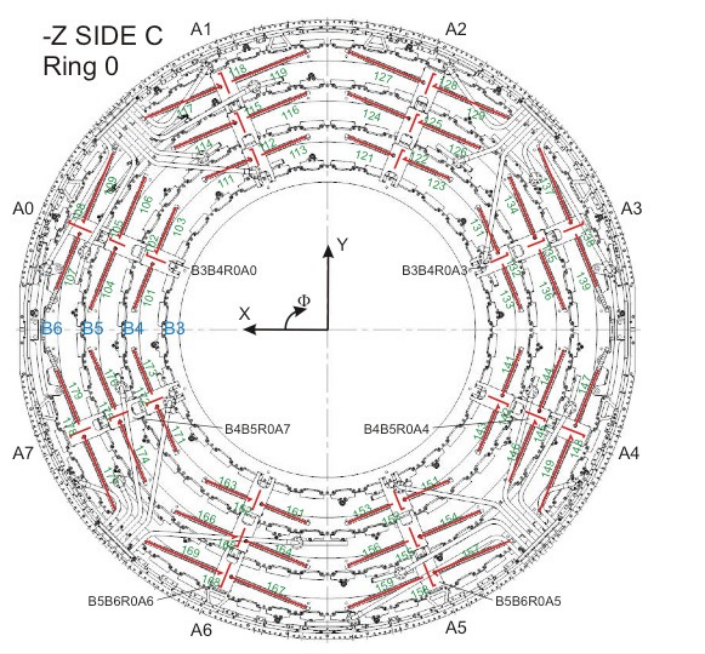
SCT FSI Grid Layout

842 GLIs distributed across the SCT

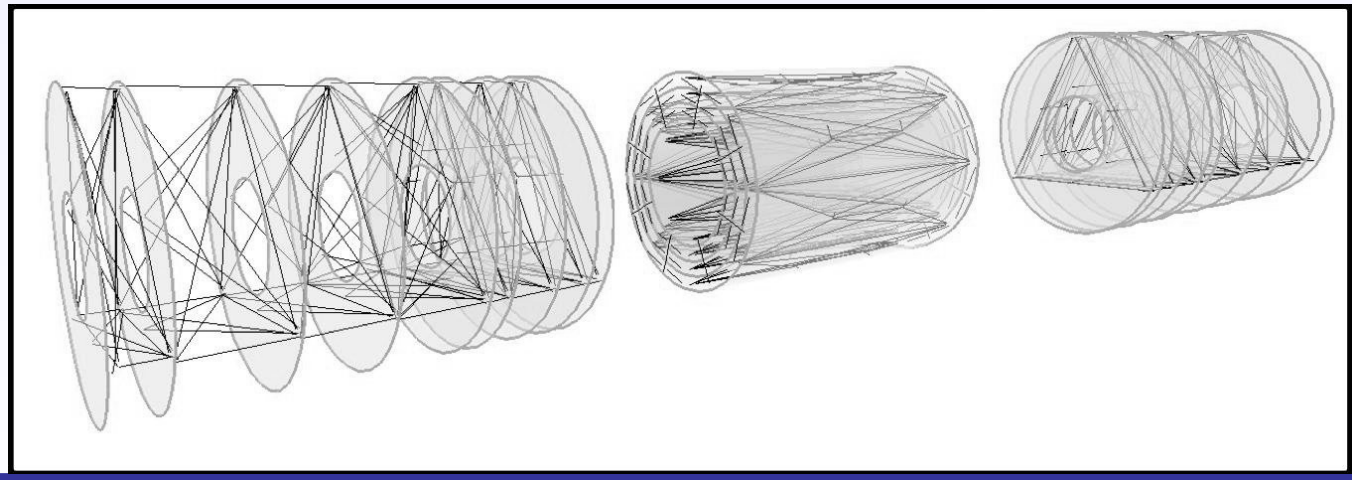
→ *512 in the barrel (including 144 lines on the flange)*

→ *330 in the end-caps*

Barrel flange details



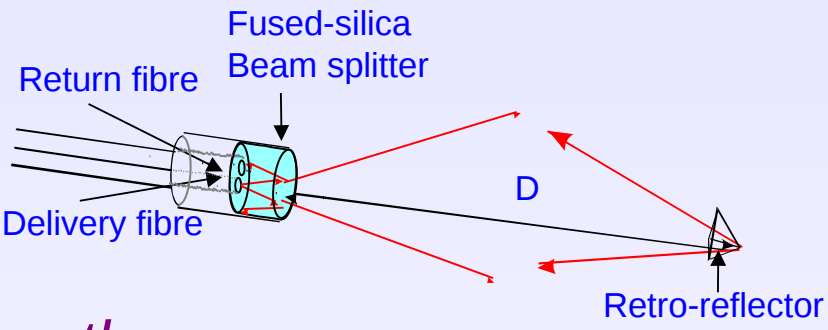
GLI length varies depending on their location, from 40 to 1500 mm



FSI principle

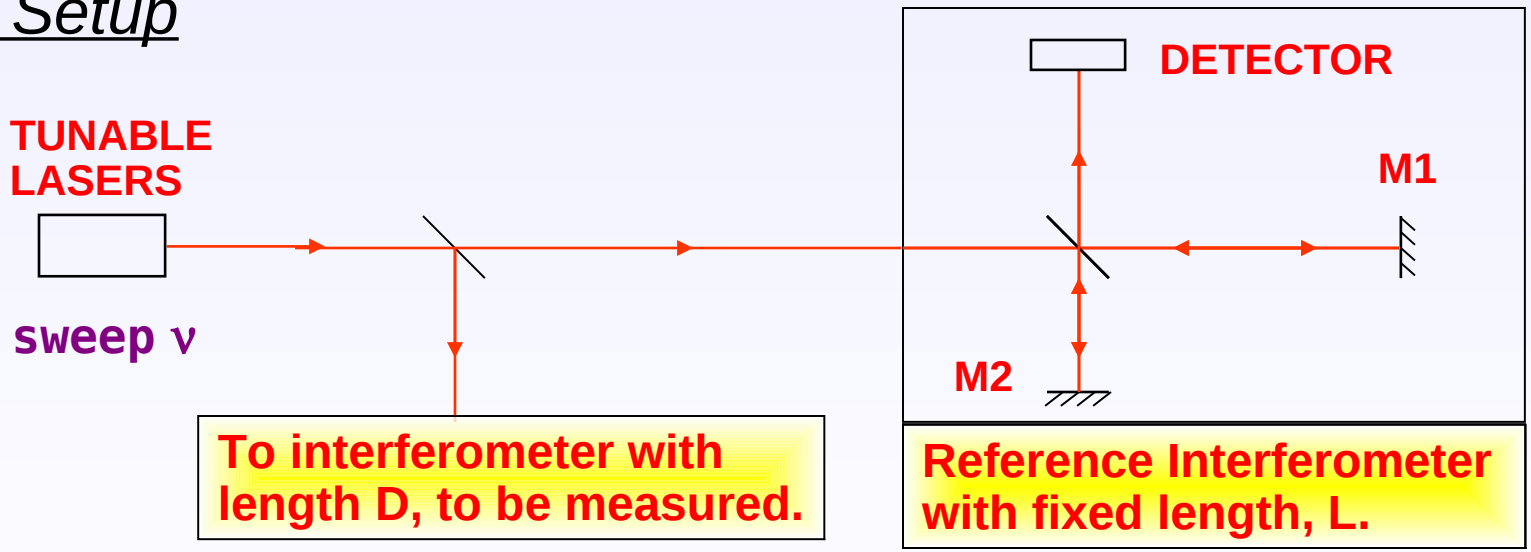
$$\frac{\Delta\theta_{GLI}}{\Delta\phi_{REF}} = \frac{D}{L}$$

GLI



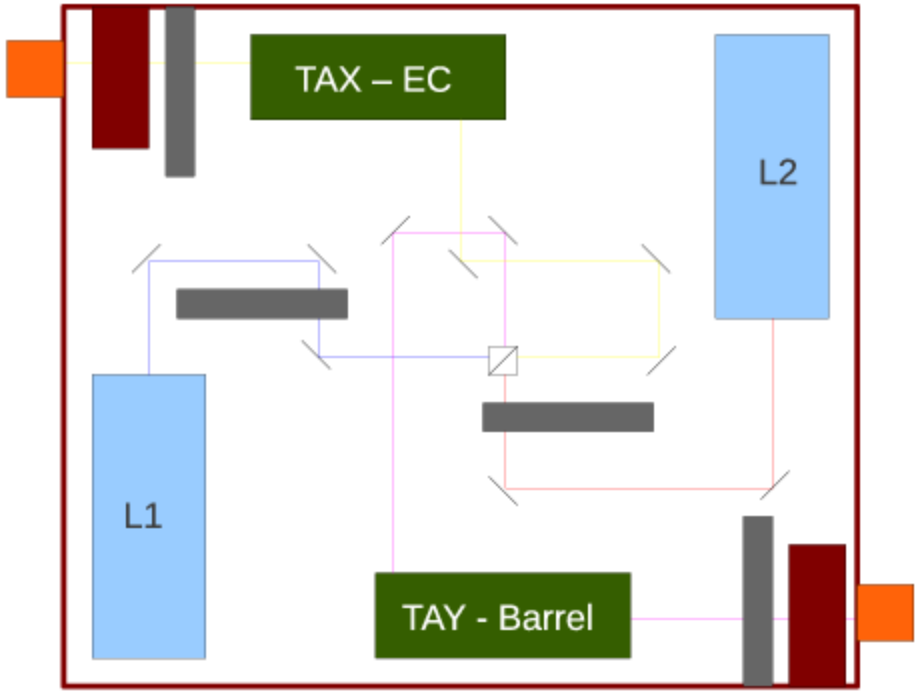
Ratio of phase changes ∝ ratio of lengths

Exp. Setup



FSI Laser System

Located on surface, providing all light needed for the FSI system to work, which is then sent to the 842 GLIs (located 100m underground) and the reference system

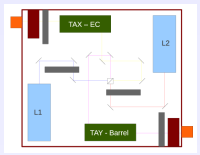


Dual laser system seeding tapered amplifiers needed to reach O(100mW) light out.

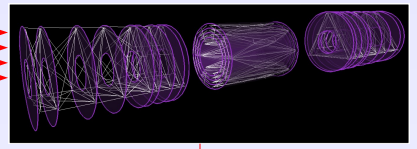
One line illuminating EC+Barrel flange, another for Barrel only.

FSI System Overview

Lasers



Fiber Splitter Tree



REF system

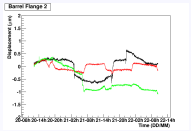
DAQ Electronics

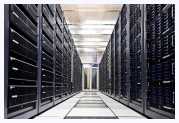
Laser light sent to inaccessible SCT detector underground, through optical fibres.
Data sent back to surface for analysis.

Data Storage

Analysis PC

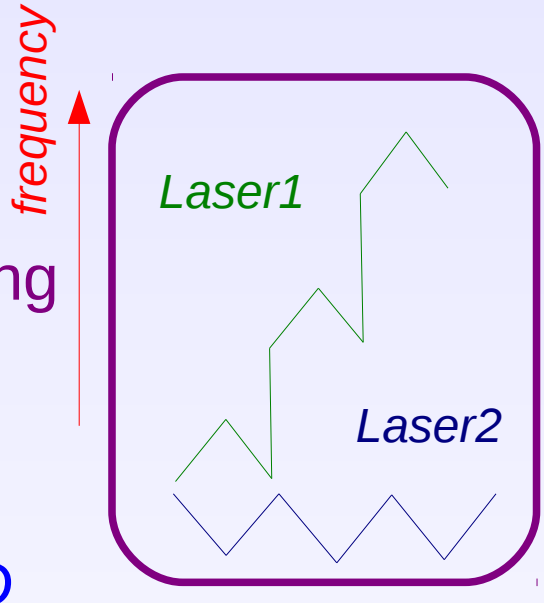
Results



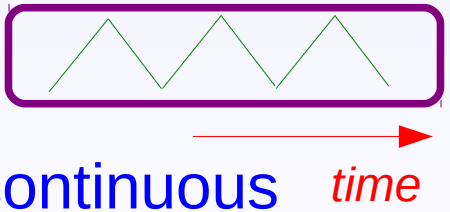


FSI Data-taking

$$\Delta\theta_{GLI} = \frac{2\pi}{c}\left(D\Delta\nu + \nu\Delta D\right)$$



- FSI data taking independent of ATLAS running
- Two types of run
  - Coarse tune scans
    - Large $\Delta\nu$, measures absolute length D
    - Precise, but slow
  - Fine tune scans (aka vibrato scans)
    - Small $\Delta\nu$, measures relative length ΔD
    - Good to catch rapid movement, needs continuous running



FSI Data Analysis

- Vibrato analysis
  - Measuring small change in GLI length
  - Needs extraction of GLI and Reference phase simultaneously
  - Absolute length obtained from coarse scans

$$\Delta D = \frac{1}{\nu}\left(\frac{c}{2\pi}\Delta\theta_{GLI} - D\Delta\nu\right) = \frac{c}{2\pi\nu}\left(\Delta\theta_{GLI} - \frac{D}{L}\Delta\Phi_{REF}\right)$$

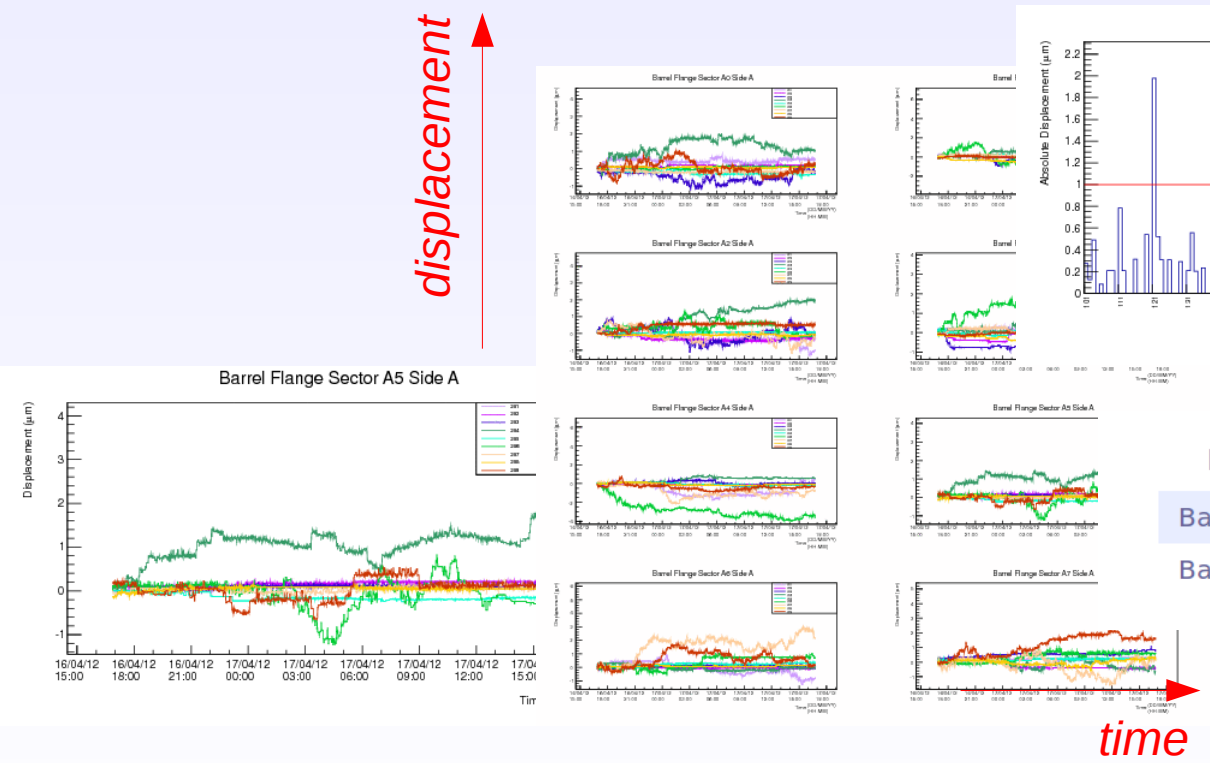
- Coarse tune scan analysis
  - Parametrise GLI intensity as function of reference phase
  - Fit intensity pattern to extract length D

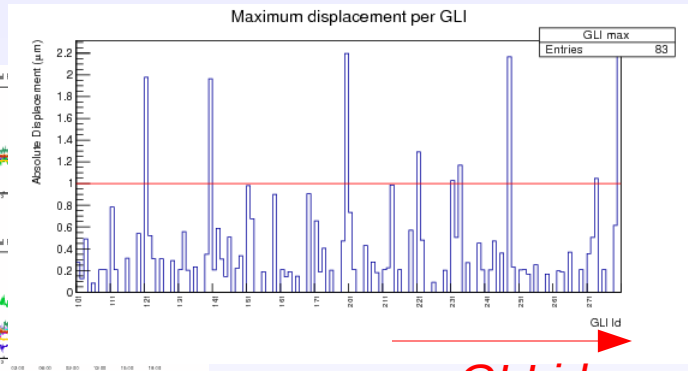
$$Y_{FIT} = I_{DC} + I_{AC}\cos\left(\frac{L\Phi_i}{D} + \alpha\right)$$

- Vibrato analysis results are shown in the following

FSI Data Analysis in 2012

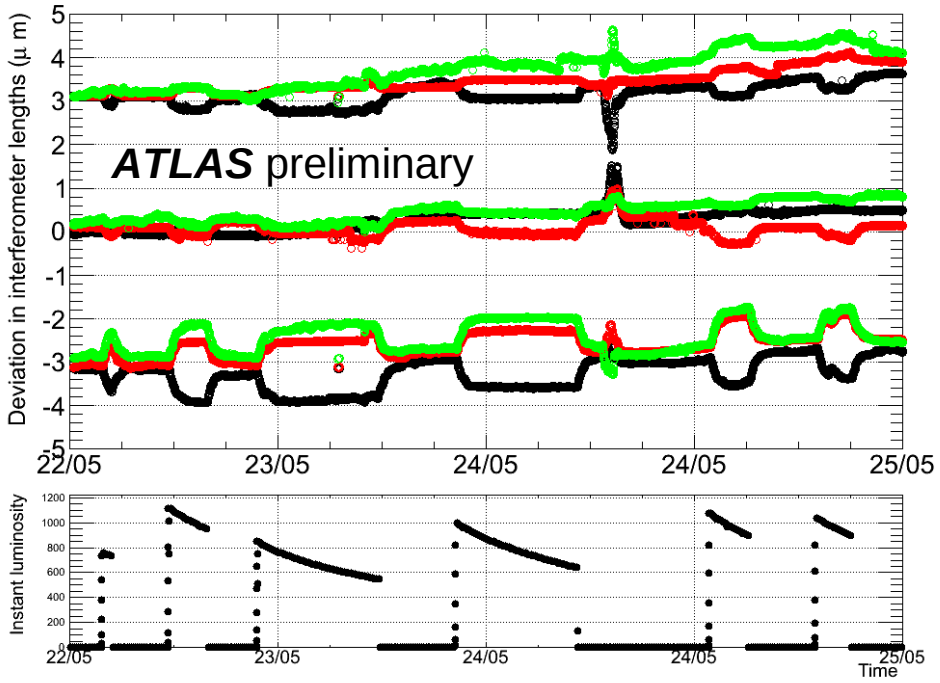
- Data analysis completely automated
  - Long continuous data acquisition in fine-tune scan mode
  - Daily analysis of 24h data slice
  - Monitoring of ΔD for all barrel flange lines





Date d/m/yyyy	3/7/2012	4/7/2012
Barrel Flange Side A	2.0 µm	2.1 µm
Barrel Flange Side C	1.5 µm	2.6 µm

LHC-correlated movement



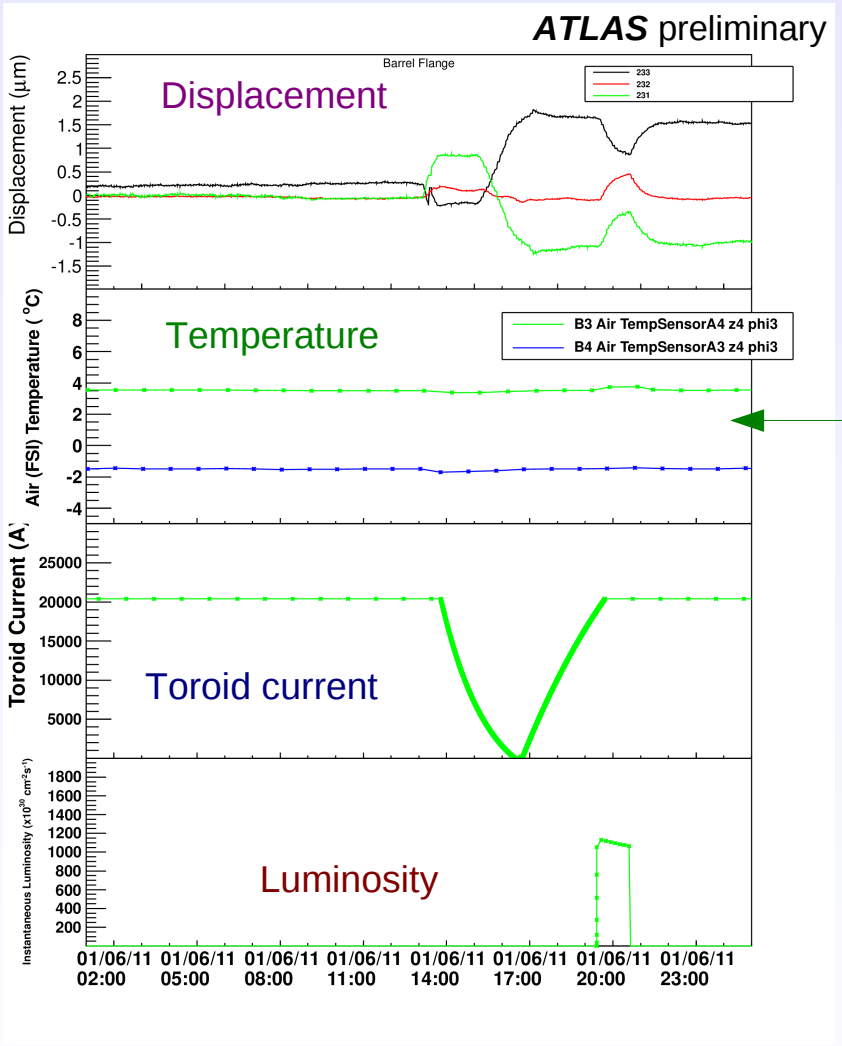
Z.Liang

- May 2011: three days of continuous LHC running
- FSI stable except for movements observed in time-correlation with LHC luminosity
- No other correlation found
- Best hypothesis: movement induced by front-end electronics activity

Top plots show changes in length for groups of 3 barrel flange GLIs at increasing radii from bottom to top

Bottom plot shows LHC luminosity

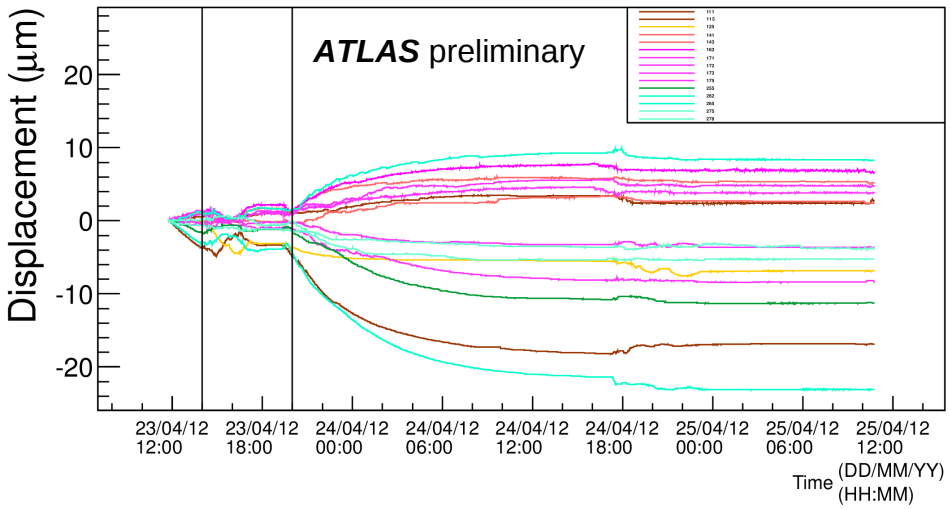
Toroid current induced movement

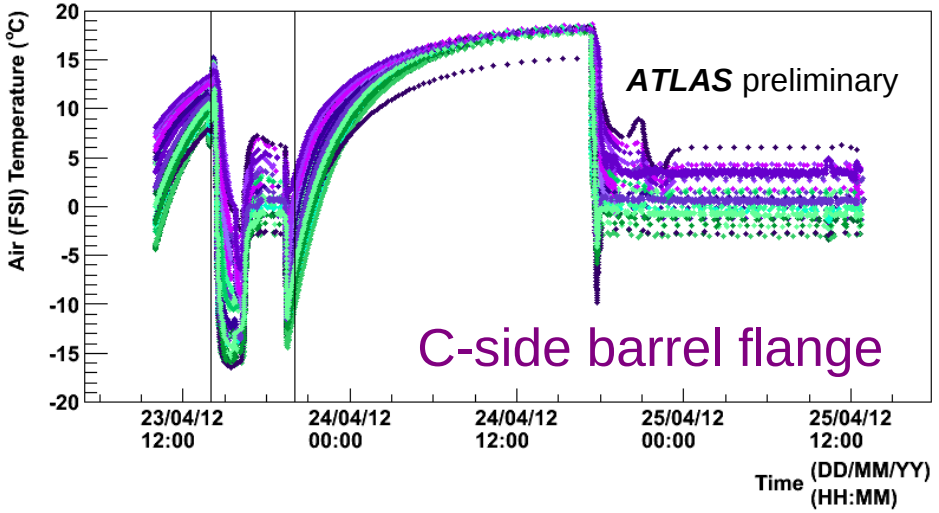


- Movement observed in barrel flange during magnet ramping cycle
  - Stable temperature conditions
  - Toroidal magnets are the skeleton of ATLAS
  - Located further away from SCT than Solenoid magnet

Cooling induced movement

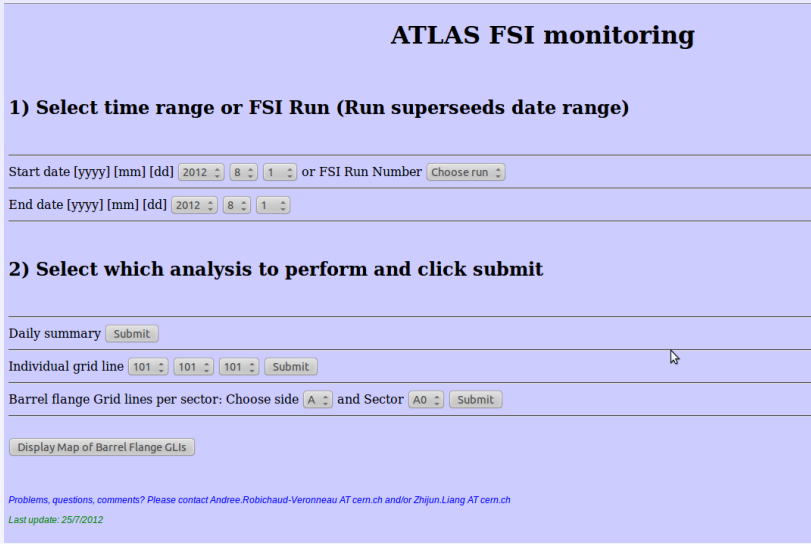
- Cooling-induced movement observed on April 23, 2012
  - Well time-correlated
  - Movement spread across all of barrel flange (both sides)
  - Rapid drop in temperature not picked up by vibrato method





FSI Monitoring

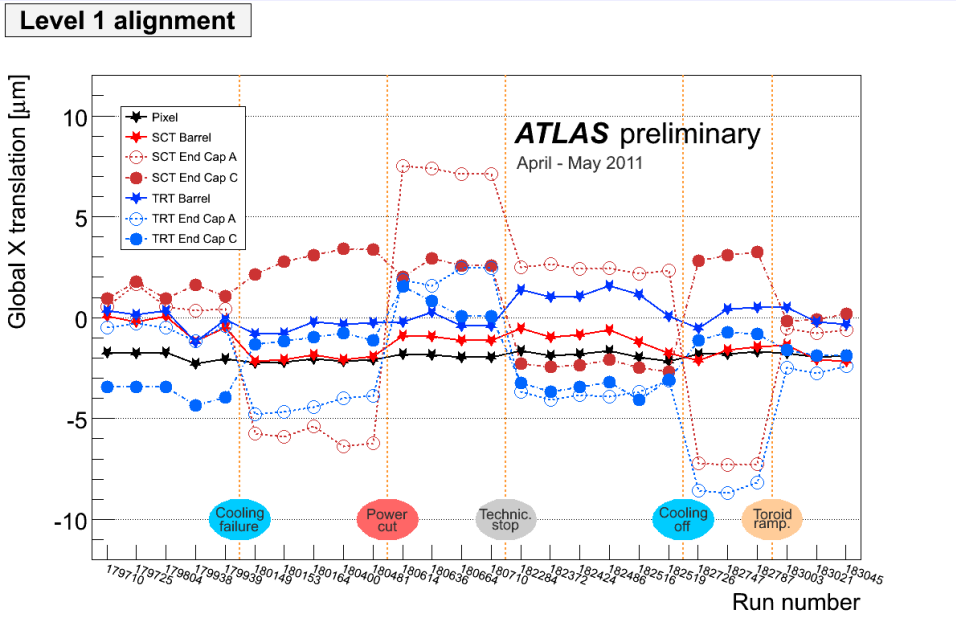
- FSI monitoring website released this year
  - For experts and non-experts
  - Ensures better communications with all people interested in FSI



- FSI data analysis on-demand
  - Displacement plots over 24h or a full run
  - Max displacement per day over desired time range
  - Individual GLIs or sectors
- http://atlas-fsi-monitoring.web.cern.ch/atlas-fsi-monitoring/

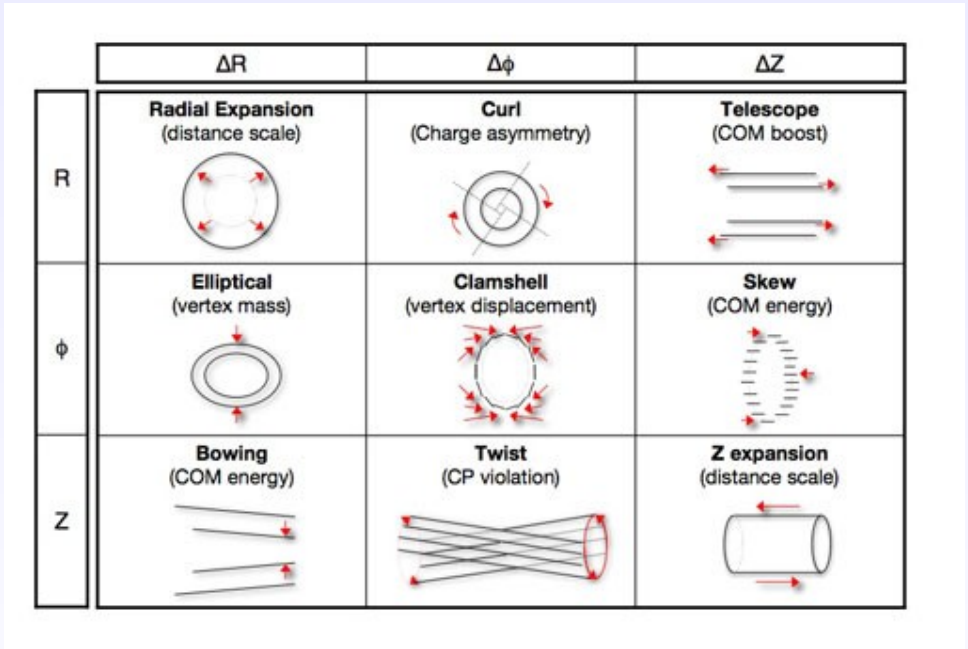
ID alignment

- Inner Detector alignment provides alignment constants used by the ATLAS event reconstruction
  - Using measured tracks from data
- High precision alignment
  - At the sub-micron level
- Time-dependence of alignment constants over months. Translations in the global x direction is shown.



FSI & ID alignment

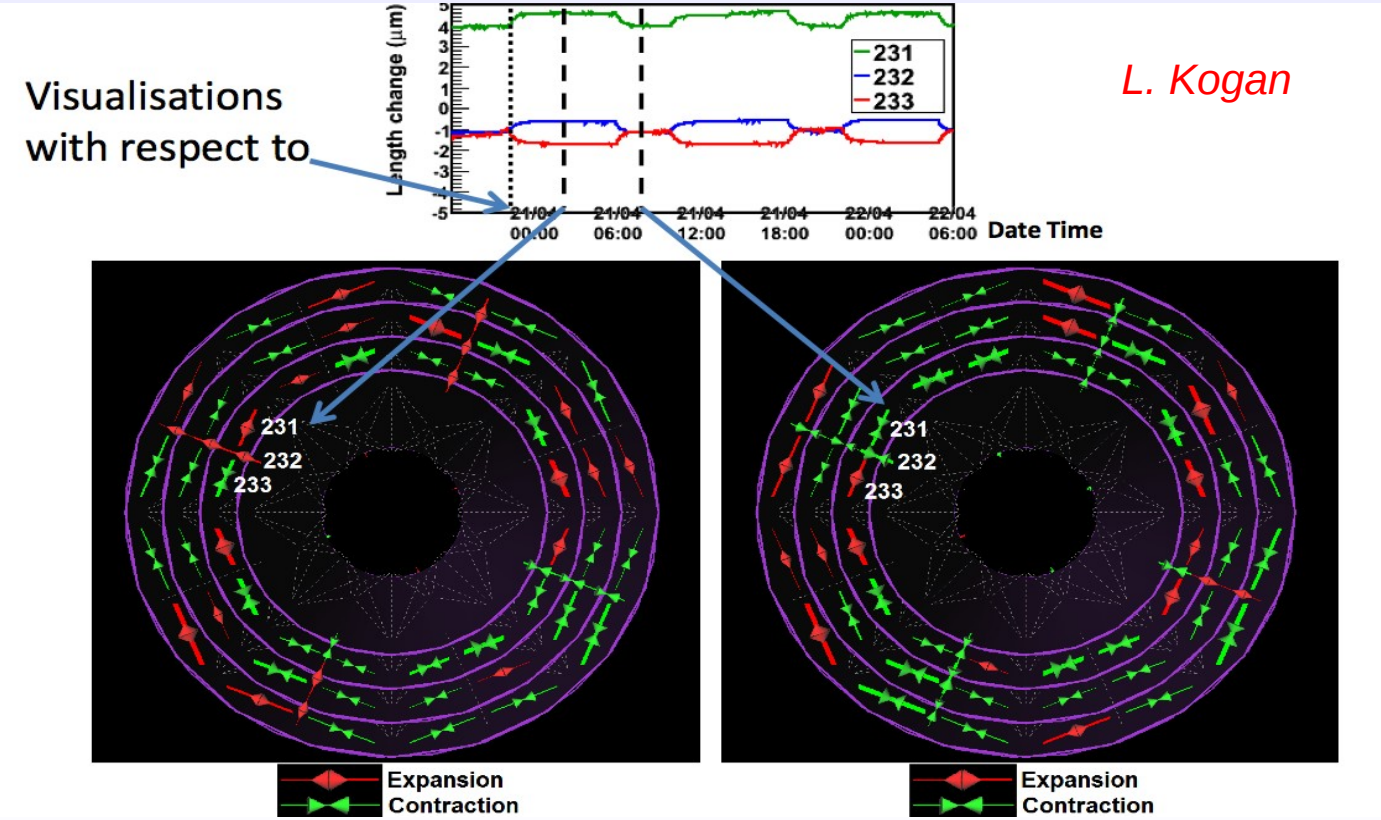
- FSI provides feedback and input to ID alignment
  - Important cross-check tool when large deviations in constants are observed
  - Provide triggers for rapid movement detected by FSI first
  - Aim at understanding weak modes



- Strong interaction between the two systems

FSI Visualizer

- New tool to interpret GLI data
- Easy visualization of GLI location
- Translation of observed displacement into structure movement (contraction, expansion)



L. Kogan

FSI Status and Outlook

- FSI running continuously and in stable condition in 2011/2012
- Ongoing effort in improving the analysis
  - Consolidating code (from LabView to C++)
  - Automation of analysis
  - Fast monitoring of current data
- Good performance of the on-detector hardware
- Hardware challenges with the laser system
  - Mode hopping of tunable lasers
  - Low efficiency light coupling into fiber
- The FSI system can do more!
  - Provide length scales estimates to ID alignment
  - Integrate more grid lines into daily analysis
  - Monitor ATLAS also during major shutdown phase (2013)

Summary

- The FSI system is used in the ATLAS SCT detector
  - Reading from over 800 interferometers simultaneously
  - Provides constant monitoring of detector stability
- Important tool for tracking detector alignment
  - Working in collaboration with track-based alignment
  - Used as cross-check and input for alignment update
- New developments
  - FSI Visualizer: understanding the FSI data
  - FSI monitoring: quick access to the analysed data
- Looking into the future
  - Ensure better performance and easier maintenance
  - Improve the current tools to make the most out of FSI for ATLAS